Real Effects of Financialization

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VER Y PRELIMINARY

Abstract

The paper aims to investigate the real effects of financialization of commodities markets. We document that financialization took a form of investment in short-term futures contracts that require regular replacement. Thus, financialization exposes the financial market to the stream of demand shocks, associated with replacement activity. If arbitrage is limited by risk aversion of financial traders, the shocks are not fully absorbed and affect futures prices. Because producers use futures to hedge, and in dispersed information setup all agents learn from the futures market, financialization shocks propagate to the real economy. We introduce inventories to diminish the price discovery role of the financial market. The media views inventories to be key to understanding what is happening in the commodity market. But we show that financialization shocks propagate to inventories as well through the physical arbitrage conducted by midstream firms. We study welfare implications and show detrimental effects of financialization, especially on producers.

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1 Introduction

In the last decade the commodities market has seen a surge in investment. Newly created instruments allowed a broad range of investors to get an exposure to commodities prices. The question arises if increased participation on the commodities market, known as financialization, may have had any detrimental effects on the real economy.

Academic literature treats financialization as an increased desire for long-term exposure to commodities. How exactly was that achieved? Financial market offers a rich set of instruments, differing by payoff structure and by maturity. Although financialization brought a huge amount of money into the market, the allocation of that investment was not uniform. Indeed, the lion’s share of investment was placed into short-term futures contracts, partially due to liquidity considerations. Investment in short-term commodities contracts has a caveat. Commodities contracts expire, and at expiration physical delivery of the commodity must take place. Not surprisingly, most traders are not eager to take the delivery. Thus, soon to expire contracts must be regularly replaced with the more distant ones, the process known as rolling. Our first observation is that as financialization allocated a considerable amount of money to short-term contracts, it also amplified the rolling process. Thus, rolling should be considered as an integral part of financialization.

Financialization exposes the financial market to the stream of demand shocks, associated with rolling activity. In principle, financial traders and arbitrageurs should be willing to step in and take the opposite side of the deal. However, it is safe to assume that financial traders and arbitrageurs are risk averse. Providing liquidity during the rolling period implies taking risks. Both, keeping the accumulated contracts until expiration, or offsetting the position before it, are risky transactions, as prices may move in the wrong direction. Therefore, financial agents require a risk premia, and futures prices tend to move, at least temporary, to offer arbitrageurs substantial compensation for risk to be taken. This is the direct effect of rolling on the underlying market. The indirect effect depends on how arbitragers and financial traders manage their accumulated positions. Imagine an arbitrageur who is also not willing to take the delivery and thus will have to offset the accumulated position in the future. Such arbitrageur will spread out the rolling shock over periods after the rolling. Similarly, if arbitrageur expects a large demand for contracts in the future and buys the contracts ahead of time to offer during the rolling, he spreads out the shock over periods before the rolling\footnote{Indeed, most of the funds are required to reveal information about assets under management and rolling dates, thus one can in real time estimate the amount of contracts to be rolled and the rolling dates.}. Therefore, our second observation is that price impact of the rolling shock may not be limited to the rebalancing period and crucially depends on the composition of financial sector.

Let’s assume that the rolling shocks are not fully absorbed and are reflected in futures prices. What are the real consequences? One channel that we consider is the hedging channel. Risk averse producers seek protection against abrupt spot prices changes and corresponding cash flow uncertainty, and engage in hedging. Hedging implies that producers may take into account the futures price when making production decisions. However, movements of futures prices due to the rolling might not be large enough to cause significant real effects. Especially, if all market
participants are aware that observed fluctuations in futures prices are not related to fundamentals. But that does not sound like as a reasonable assumption and it brings us to the second channel. Financial market aggregates dispersed information and gives agents opportunity to learn the missing pieces. Financialization shock, when propagates to futures prices, obstructs learning, as some agents unaware of financialization shock would mix it up with arrival of fundamental information, either supply or demand related. Thus, for a given degree of propagation of rebalancing shocks to futures prices, we may expect to see larger real effects. However, the degree of propagation of shocks is endogenous. Our third observation is that in equilibrium, willingness of risk averse financial traders and arbitrageurs to absorb the rolling shock may be smaller, if uncertainty about future spot price movements is larger due to worse information aggregation. And one may expect larger real effects.

As we would like to emphasize the informational role of futures market, it is important to adequately describe and model alternative learning opportunities that agents have in addition to financial market. Those include learning from spot price and from inventories. Our final observation is that most agents are not able to learn from the spot price and instead use inventories as a substitute. That might seem wrong, as current spot price should be an ideal direct source of information. So why learning from spot price might not be an option? Because physical markets are opaque. A single spot price that reflects current spot market conditions may not exist. Above all, any commodity is not a homogeneous product. More importantly, the bulk of physical trading is conducted bilaterally and privately. One can argue that there exist price reporting agencies, platforms such as Platts, that are supposed to collect and consolidate information in a single spot commodity price index. However, the platforms have been subject to substantial criticism, mainly on the ground of insufficient voluntary disclosure. Although, more important obstacle is the practice of many commodity trading firms to rely on some benchmark in setting the price. According to FERC 2009 survey that studied physical natural gas market, for every MMBTu reported to an index publisher, more than 6 MMBtu rely on that price. Analysis of the midstream company Plains All American Pipeline data on spot oil prices in different locations, shows that the local prices tend to be tied to the WTI futures price, with WTI futures contract traded on NYMEX (see figures 12 and 13). Indexing dampens price discovery, and actual spot market conditions may be unobserved by all agents except for midstream companies that have wide network of pipelines, cover multiple local markets, and thus may aggregate information coming from various local sources. But that in turn means that rational agents should consider inventories as an alternative source of information that reflects private information available to the midstream sector. Indeed, financial reporters carefully follow, say, oil inventories (see appendix). For example, a build up in inventories reflects weak demand conditions in the current market, as owners of storage facilities find it optimal to buy commodity on the spot market, store it for a while and sell back when demand conditions improve. Therefore, it is important to allow agents to observe inventories, as potentially being more informative about fundamentals and less prone to noisy financial shocks. In principle, that should diminish informational role of financial market. However, as we will see the rolling shock passes through to inventories as well, and a build up in inventories may actually reflect a financialization shock, and be unrelated to current of future market conditions.
We build an asymmetric information model with infinite number of periods and one commodity good, to study real effects of financialization. The model resembles some features of Goldstein and Yang (2015). Consumers of oil purchase it each period on the spot market and are subject to demand shocks. Production side is represented by producers of oil and distributors, or midstream companies, that may store and reallocate oil in between periods. Risk averse producers engage in financial market to hedge spot price risk. Financial market is represented by two futures contracts with different maturities available for trading. Risk averse financial traders and arbitrageurs are willing to trade with producers, thus, providing insurance, but require compensation for risk taken. Financial sector is not homogeneous: financial traders keep contracts until expiration, whereas arbitrageurs offset position before expiration. Financialization shock is modeled as exogenous demand shock that affects both futures contracts, with stochastic rolling direction and size. The economy is hit by three type of shocks: supply shock, demand shock and financialization shock. Producers observe supply shocks, midstream companies observe current and future demand shocks and spot price, arbitrageurs observe financialization shock. All agents may also learn from futures prices and inventories. Using the model we study the real effects of financialization and compare full information case and with the benchmark case where agents have to learn from prices. We also introduce possibility of front-running, giving arbitrageur a signal about future rolling and studying if transparency is important.

First, we analyze the response of the economy to one time financialization shock. Limited capacity of financial sector to absorb shock ends up in futures prices moving in the direction of financialization shock, which in turn leads to changes in production, inventories, spot prices, and eventually welfare of producers and consumers. However, in the full information case the effect of financialization is limited. Introduction of learning channel considerably amplifies the effect. Financialization exposes the financial market to the stream of demand shocks, associated with rolling activity. Propagation of non-fundamental shocks to futures prices obstructs learning, and thus, increases uncertainty about future spot price movements. That in turn further decreases the willingness of financial traders to absorb the rolling shocks. The price impact of the rolling shocks ends up being large enough to trigger sizable real effects. We study welfare implications of financialization, and show that financialization significantly decreases welfare of consumers and producers, especially when learning channel is active.

The paper’s contribution is mainly twofold. We document specific features of financialization and build a model to study the effect of rolling on the real economy. We show non-trivial effect of rolling on the term structure that propagates to the real economy. The paper is organized as follows. Section 2 - literature. Section 3 - motivating fact. Section 4 - model. Section 5 - solution. Section 6 - results. Section 7 - discussion and conclusion.

2 Literature

Academic literature mostly shares the view of financialization as of increased demand for long exposure to commodities. Grounded on an unprecedented spike in oil prices in 2008, such a view suggests that financialization could put upward pressure on futures prices, that could spill over to
spot prices. A number of papers investigate empirically the impact of financialization or speculation on futures prices and volatility, including Masters (2008), Sanders and Irwin (2011), Brunetti et al. (2011), Singleton (2013), Tang and Xiong (2012), Stoll and Whaley (2010), Hamilton and Wu (2015), and on spot price Kilian and Murphy (2014). Most papers either do not confirm the price impact at all, or find only weak connection. Many papers use CFTC public reports and proprietary data to estimate the investment in commodities tied with index investment. However, the level of aggregation and timing issues impose severe limitations on usage of such data. Henderson et al. (2015) study the impact of issues of commodity-linked notes on commodity prices and find a significant impact of futures prices. Second strand of literature focuses on rolling feature of financialization: Mou (2011), Selezneva (2010, 2015), and Neuhierl and Thompson (2014). These papers jointly argue that financialization affects the difference between the nearby contract and the next futures contract, and document the front-run on future rolling.

Our paper relies on two mechanisms: limited absorbing capacity of financial sector for shocks to affect futures prices and learning from financial market for shocks to have real effects. Among the papers that focus on limited absorption capacity of financial sector is Hamilton and Wu (2015). The paper argues that financialization affects futures prices through risk premia, as arbitrageurs should be motivated to absorb the financialization shock. However, Hamilton and Wu focus only on the effect on financial market and do not consider expiration and/or rolling issues. Gabaix and Maggiori (2014) study limited absorbing capacity of financial sector on FX market, and show that both level and volatility of exchange rates are affected, and that imperfection of financial market has real consequences for output and risk sharing. Research that studies learning function of commodity market includes Sockin and Xiong (2015). Commodity is used in production of final good. Spot market for commodity serves to provide agents with information about strength of global economy, but that information is contaminated by supply noise, thus a high spot price may induce producers to overestimate the strength of the economy and demand extra amount of commodity. Grossman (1977) uses an asymmetric information model to study why futures markets exists in some commodities and not others. In the paper futures market also serves as a source of information, and the incentives to develop futures market depends on the ability of the spot market to convey information from informed to uninformed.

The closet to ours Goldstein and Yang (2015) that considers both mechanisms and also studies the real effects of financialization. However, Goldstein and Yang model financialization as an increase in the number of financial traders willing to trade with producers, and thus differ substantially from our view of financialization. Our model also differs from GY as we consider consider infinite period setup to be able to assess long-term consequences of financialization shocks; we have richer set of financial contracts and richer set of financial agents. In GY financial traders keep contracts until expiration. But as was discussed above, in reality statistical arbitrage is much more popular. Arbitrageurs tend to offset accumulated position before the expiration date, thus we introduce arbitrageurs that could trade second futures contract in one period, and then offset the position in the next period. Finally, in the real sector we introduce inventories and midstream energy companies that control inventories, and we allow all agents to extract information from inventories, as inventories are potentially more informative about fundamentals and less prone to
noisy financial shocks, thus possibly diminishing informational role of financial market.

Inventories, informational role of inventories...

to be completed

3 Financialization as investment in short-term contracts

The commodities market has seen a surge of investment in the last decade. Access to the commodities market gives a nice diversification benefit to agents active on the equity market. The energy market has attracted particular attention, partly because oil is considered to be a natural hedge against inflation. Therefore, low cost and convenient access to commodities for small investors, was essential. And innovation of index products and exchanged traded products allowed that to happen. ETPs basically allow to replace trading of the underlying commodity with trading of the liquid shares on the stock market. But of course, either the managers of the funds (in the case of exchange traded funds), or the issuers of the instruments (in the case of exchange traded notes linked to the performance of a commodity, for instance), have to translate the investment in the products to the direct position in the underlying market. That is required either by tracking or by hedging of one’s own exposure. Therefore, the liquidity of the underlying market becomes an issue. At the end, most ETPs end up being related to the liquid short-term contracts, predominantly short term futures.

Consider, first the oil market. Indeed, figure 14 represents open interest in crude oil futures by maturity. One can notice that open interest declines very quickly as maturity increases. Not surprisingly, the liquidity on the short end of the term structure curve turns out to be much larger. One of the first and largest exchange traded funds that offered low cost exposure to the oil market, was the United States Oil Fund (USO). In line with our argument, the Fund invests in the nearby futures contracts on WTI oil traded on NYMEX. Holding short-term contracts in its portfolio, the Fund has to roll the contracts every month. Until March, 2009 the Fund used to roll the entire portfolio in a matter of one day, but then the rolling period was extended. The Fund attracted about $4 bln of assets in February, 2009, and thus, had to roll the substantial number of contracts, equal to 30% of the total open interest in the nearby contract. As of March, 2015, the United States Oil Fund again had $3.3 bln of assets under management. Moreover, nowadays there are multiple funds and ETNs that also invest in the nearby futures contract on WTI, and, hence, have to roll in the same fashion: OIL, DBO, leveraged UWTI, and similar. Most of the oil funds nowadays follow S&P GSCI® Crude Oil Total Return Index, that implies rolling in 5 days at a constant rate. So although rolling is extended to 5 days, the amount of contracts to be rolled is still large and predictable. In addition to the USO the United States 12 Month Oil Fund (USL) was launched. The USL holds a portfolio of 12 different maturities contracts. Again, each month the Fund has to roll a fraction of its portfolio to replace expiring contracts. Thus, the Fund still adds partially to the rolling process. Importantly, the USL has not attracted much assets, compared to USO, and never exceeded $100 million threshold. Thus, investors also seem to prefer exposure to short-term contracts. Similarly, in the gas market, the first fund that was established and gained substantial interest was the United States Natural Gas Fund (UNG). The Fund invests in the nearby futures on natural gas also traded at the NYMEX. The UNG was launched in 2007, and
attracted a massive $4.6 billion in assets under management at the end of 2009, again implying massive monthly rolling. Similarly, the 12 month natural gas fund did not even come close to the size of UNG.

One of the largest indexes that cover broad commodity sectors, is the Standard and Poor’s - Goldman Sachs Commodity Index (SP-GSCI). Although the index puts some weight on a wide range of commodities, 80% is related to energy markets and involves investment in crude oil, natural gas, heating oil, and similar. The SP-GSCI assumes tracking of the nearby energy commodities contracts and prescribes monthly rolling during 5 days. With other commodities, rolling might happen only 8 to 4 times a year, depending on which futures are offered. However, in all cases, short-term contracts are used as an underlying security, as liquidity decreases substantially with maturity. Hence, any instrument that is linked to the index, will force its issuer to roll according to the same schedule in order to be able to hedge the exposure.

Therefore, one can see that although financialization brought substantial investment to the commodities market, most of it was allocated on the short end of the term structure curve.

4 Model

We consider an asymmetric information model similar to Goldstein and Yang (2015). Consider an economy with infinitely many periods. There are two consumption goods, a commodity, let’s call it oil, and a numeraire. Oil is produced each period and available for consumption in the next period. Every period commodity is traded on the spot market. Producers of oil are risk averse and use financial market to hedge their exposure to spot prices. Oil produced is either consumed by consumers, or stored by distributors for the next period, only distributors possess the storage technology. Financial sector consists of financial traders and arbitrageurs, willing to provide insurance for risk averse producers. Finally, the Fund carries the collective image of funds and instruments related to financialization. The Fund is responsible for financialization shocks.

Financial market is represented by two tradable futures contracts with two different maturities, one or two periods from now. We will call the futures with the closest expiration date as the nearby contract, and the futures with expiration two periods from now - the next out contract, or second month contract. Every period the contract that was the nearby contract last period expires, and a new second month contract becomes available for trading. Expiration of contract assumes the physical delivery of the commodity. Thus, if in period $t$, the nearby futures contract is traded at price $f_{1,t}$, than a purchase (sale) of one unit of that futures contract would imply the purchase (sale) of one unit of commodity in period $t + 1$ at price $f_{1,t}$. Similarly, if in period $t$, the next out futures contract is traded at price $f_{2,t}$, than a purchase (sale) of one unit of that futures contract would imply the purchase (sale) of one unit of commodity in period $t + 2$ at price $f_{2,t}$. However, one can also offset the position before the expiration, in the next period, as the futures contract might also be sold (bought) in period $t + 1$ at price $f_{1,t+1}$, when it becomes the nearby contract. Finally, a risk-free asset is available, but risk-free rate equals zero.

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\(^{2}\)Each period is assumed to be equal to one month in line with standard expiration schedule of futures on most important commodities
Agents include consumers, producers, distributors, financial traders and statistical arbitrageurs. We first define preferences and choices of each group of agents. Later we will specify the information that each group possess and the learning process. Even though we work with infinite period setup, most agents would be short-lived.

4.1 Real sector

Agents directly involved with production, distribution or consumption of commodity are called real sector agents. The real sector agents are represented by producers of oil, oil distributors or midstream companies, and consumers of oil.

4.1.1 Consumers

Consumers are modeled in an over simplistic manner with a goal of getting a demand curve, similar to Goldstein and Yang. In each period a measure one of new consumers arrives in the morning, buys oil on the spot market, consumes it, and leaves. Consumers have the following preferences over consumption of commodity, $y_t$, and numeraire, $m_t:

$$U_C(y_t) = -\frac{1}{2}y_t^2 + \theta_t y_t + m_t,$$

where demand shock $\theta_t$ reflects any kind of uncertainty coming from the demand side and $\theta_t \sim N(\bar{\theta}, \sigma_{\theta}^2)$. Consumers face spot price of oil, $p_t$, therefore a representative consumer solves

$$\max_y \left( -\frac{1}{2}y_t^2 + \theta_t y_t - p_t y_t \right),$$

thus implying a demand curve

$$y_t = \theta_t - p_t.$$

4.1.2 Producers

A representative oil producer of generation $t$ in period $t$ decides how much oil to produce to be sold in the period $t + 1$. That is built in to reflect a sluggish nature of commodity production and inability to respond instantaneously to demand shocks. Thus producer faces uncertainty regarding the future spot price of commodity, and being risk averse, producer wants to hedge that risk. After oil is produced and sold, the producer leaves the market.

A representative producer has costs of production of $x$ units of commodity $C(x) = c_t x_t - \frac{1}{2} x_t^2$, where $c_t \sim N(\bar{c}, \sigma_c^2)$ and reflects uncertainty originating on the supply side of the market. Producer participates in futures market, but may buy or sell only nearby futures. That is assumed for simplification reasons, but it is also in line with a general fact that producers are not usually
allowed by lenders and shareholders to trade on the financial market for reasons unrelated to hedging activity, in other words only contracts directly relevant to hedging activity may be traded. In our case producer producers oil one period ahead and, therefore, may only trade the nearby futures. Futures contract has a price $f_{1,t}$, buyer of a futures contract will buy one unit of commodity at price $f_{1,t}$ in the next period, and therefore may immediately sell it on the spot market for price $p_{t+1}$, thus defining payoff $p_{t+1} - f_{1,t}$.

Terminal wealth is defined by real activity performance and by proceeds from financial market:

$$W^p_t = (p_{t+1} - c_t)x_t - \frac{x_t^2}{2} + (p_{t+1} - f_{1,t})d_{1,t},$$

where decision variable include $x_t$ - how much to produce and $d_{1,t}$ how much to hedge. Producer sells its product on the spot market and gets any proceeds from the financial market. Producer has CRRA preferences over terminal wealth $W^p_t$ with risk aversion parameter $\alpha$ and, thus, solves

$$\max_{x_t, d_{1,t}} E \left( -e^{-\alpha W^p_t} \mid Info_P \right).$$

Notice that we do not restrict $d_{1,t}$ to be equal to $x_t$. So in principle a producer may buy more or less futures contracts that he actually needs to fully hedge the production, and therefore by doing this producer engages in speculative activity. Although we do not want to put restrictions on $d_{1,t}$, we make $\alpha$ considerably large to avoid large speculation activity by producer.

### 4.1.3 Midstream companies/distributors

Although we postulated inertia in oil production and inability of producers to respond to production shocks, we assume that another venue exists to regulate supply and smooth demand shocks at least to some extent. We introduce distributors - agents that have access to inventories and thus can store oil from one period to another. So distributors buy oil at spot price from producer, keep it in storage until the next period comes, and than sell it back on the spot market. We also assume that each period new generation of distributors is born, conducts one storage operation, get the proceeds next period and dies. The terminal wealth of representative generation $t$ distributor is given by

$$W^d_t = p_t(-I_t) + p_{t+1}I_t,$$

where $I_t$ is inventory built at period $t$ to be sold in period $t + 1$ at spot price $p_{t+1}$. Distributors have CRRA preferences with $\beta$- parameter of risk aversion, and solve

$$\max_{d_t} E \left( -e^{-\beta W^d_t} \mid Info_D \right),$$

Notice that distributors have no access to financial market. Thus, if they have any private information relevant for future spot prices, that would use it by storing more or less oil, fundamental reaction. When introducing distributors, we have in mind midstream energy companies that operate oil infrastructure - pipelines and storage facilities and may store oil from period to period. Examples include Plains All American Pipeline and similar.
4.2 Financial sector

Financial sector is assumed to facilitate risk sharing, providing insurance to producers.

4.2.1 Financial Traders

Producers demand futures contracts to hedge spot price risks. Financial traders step in to take the opposite side, thus, provide insurance to producers. However, being risk averse, financial traders require risk premia for that. We also allow financial traders to trade both futures contracts at the same time. A generation $t$ of financial traders is born in period $t$, trades both futures contracts in period $t$, gets proceeds from purchased nearby contracts in period $t+1$ and from purchased second period contracts - in period $t+2$, and then dies. No additional trading happens in between. Financial traders are assumed to have CRRA preferences with risk aversion $\gamma$, where terminal wealth of generation $t$ financial trader is given by

$$W_{F}^{F_t} = (p_{t+1} - f_{1,t})d_{1,t}^F + (p_{t+2} - f_{2,t})d_{2,t}^F.$$  

First term corresponds to the realized proceeds of purchase of $d_{1,t}^F$ units of the first term contract in period $t$ and holding the contracts until expiration in period $t+1$, when the units of commodity are delivered at price $f_{1,t}$ and immediately sold at the spot market at price $p_{t+1}$. Second term represents trading of $d_{2,t}^F$ units of second month contract in period $t$, holding the contracts until expiration in period $t+2$. In principle financial traders could rebalance the portfolio in period $t+1$, however, we preclude that behavior. Other agents will be able to trade like this and we would like to emphasize the difference and implications of such heterogeneity. Financial traders solve

$$\max_{d_{1,t}^F, d_{2,t}^F} E \left( -e^{-\gamma W_{F}^{F_t}} | Info_{F_t} \right).$$

To sum up, financial traders represent a large sector of traders on financial markets that tend to rebalance their portfolio only infrequently.

4.2.2 Arbitrageurs

The last group of agents is represented by arbitrageurs or statistical traders. In contrast to financial trades, arbitrageurs close their position before second month contract expires. We have in mind a group of sophisticated investors that is active on many markets and often rebalances portfolio. We assume that statistical traders trade first contract as all the other agents- meaning that they are ready to take the delivery in the next month. But we assume that when trading second contract, statistical traders do not wait for the delivery month and close the position one month before that. Thus terminal wealth of generation $t$ statistical traders is given by

$$W_{FR}^{F_{R_t}} = (p_{t+1} - f_{t,1})d_{1,t}^{FR} + (f_{1,t+1} - f_{2,t})d_{2,t}^{FR}.$$
First term is standard. Second term means that the trader buys \( d_{2,t}^{FR} \) distant futures contracts at price \( f_{t,2} \), and sells all of them in period \( t + 1 \), when the contracts become first period contracts. Similar to other agents statistical traders have CRRA preferences with \( \delta \) parameter of risk aversion. Arbitrageurs solve

\[
\max_{d_{1,t}^{FR}, d_{2,t}^{FR}} E \left( -e^{-\delta W_{FR_t}} | I_{FR_t} \right).
\]

4.3 The Fund/financialization shock

The specific feature of the financialization shock in the oil market is periodic mechanical rolling. Thus each month a number of first period contracts is sold and a number of second period contracts is bought. Therefore, in our model we introduce financialization shock as \( q_t \) number of first contracts that have to be sold in period \( t \) and \( q_t \) number of second contracts have to be bought by so called the Fund. The Fund aims to reflect the newly created demand for oil exposure that gets reflected in investment in various index funds, ETFs and similar venues. Thus we do not model explicitly the behavior of Fund’s investors. Instead we assume a purely exogenous shock \( q_t \sim N(\bar{q}, \sigma_q^2) \) and study its affect on the economy.

Other cases to be completed...

4.4 Market clearing

Spot market clearing implies that oil demanded \( y_t \) equals oil stored from previous period \( I_{t-1} \) plus \( x_{t-1} - I_t \) fraction of total amount produced for the current period and not stored until the next one by distributors, or

\[
y_t = \underbrace{I_{t-1}}_{\text{distributor}_{t-1}} + \underbrace{x_{t-1} - I_t}_{\text{distributor}_t}.
\]

Futures market should clear for both contracts. First period contracts are traded by producers, financial traders, current arbitrageurs that buy first period contracts and previous generation of arbitrageurs that close their position (sell \( d_{2,t-2}^{FR} \) number of contracts that used to be second period contracts last period and are first period contracts now) and the Fund, that sells first period contracts in amount \( q_t \). Because futures contracts by definition are in zero supply it must be the case that

\[
d_{1,t} + d_{1,t}^{FR} + d_{1,t}^{FR} - d_{2,t-1}^{FR} - q_t = 0.
\]

Second period contracts are traded by financial traders, arbitrageurs and the Fund that buys second period contracts in amount \( q_t \)

\[
d_{2,t}^{FR} + d_{2,t}^{FR} + q_t = 0.
\]
4.5 Information structure

To complete the model we need to specify the information structure, mainly a set of exogenous and endogenous signals that each type of agents privately observes. In the model we introduced 3 kinds of shocks: demand shock $\theta_t$, supply shock $c_t$, and financialization shock $q_t$. Of course, fundamental supply and demand related signals must be observed by consumers and producers - directly involved in production and consumption process. Thus demand shock $\theta_t$ is observed by consumers, $c_t$ - by producers. And then of course, endogenous prices can serve as signals as well - both spot price $p_t$ and futures prices $f_{1,t}$ and $f_{2,t}$.

As was discussed before, physical market of commodity is quite opaque. Based on that we are comfortable making the assumption of spot price being unobservable by all agents except for oil distributor. As was said before, by distributors we assume midstream companies that are ground-based and thus may have an idea of a spot price, aggregating all the information coming to them from various local markets.

Moreover, they may have a better idea of future demand prospects as well, receiving in advance the demands from manufacturing companies, refineries and similar firms. Thus we also assume that distributors get a signal about future demand prospects, $s_t = \theta_{t+1} + \varepsilon_t$.

Thus looking at the amount of oil stored for the next period, market participants may extract information about future prospects of the market as well. Therefore, inventories can serve as endogenous signal as well. And the press quite carefully follows the announcements about oil inventories in Cushing.

Financialization in the form of investment in various ETFs and index funds that have to roll the entire portfolio also means that sophisticated investors, might in advance observe financialization shock. Most of the funds publish assets under control daily. Moreover, rolling date are known in advance. In many cases, for example USO rolling before March, 2009 occurred in a matter of one day. Thus one can safely assume that a clever enough investor may find out the amount of rolling in advance. Therefore, we assume that arbitrageurs observe a signal about future financialization shock, observe $m_t = q_{t+1} + \eta_t$ in period $t$. And we will change the precision of that signal to study the effect of front-running activity on the market.

Finally, for technical reasons to simplify the analysis we assume that past shocks get revealed. So at the beginning of period $t$, period $t-1$ and all earlier shocks are publicly known, which allows to avoid accumulation of mistakes. Define $t$-period shocks as $V_t = \{\theta_t, c_t, q_t, s_t, m_t\}$. Define history up until period $t$ as $H^{t-1} = \{V_{t-1}, V_{t-2}, ..\}$- all shock up to and including period $t-1$.

That being said we assume the following information structure, where we keep only relevant agents that extract information:

Distributor

$$I^D_t = \{\theta_t, s_t, f_{1,t}, f_{2,t}, p_t, H^{t-1}\}.$$ 

Producer

$$I^P_t = \{c_t, f_{1,t}, f_{2,t}, H^{t-1}\}.$$
Financial Trader

\[ I^F_t = \{f_{1,t}, f_{2,t}, H^{t-1}\} \]

Arbitrageur

\[ I^{FR}_t = \{m_t, f_{1,t}, f_{2,t}, H^{t-1}\} \]

whereas full information would be just learning the whole history \( I^{full}_t = H^t \).

5 Solving the model

Let’s first solve maximization problems of each type of agents and then use market clearing conditions to get laws of motions of endogenous prices in general form.

5.1 Solving maximization problems

Maximization problem of producers implies that

\[ x_t = f_{1,t} - c_t, \]

\[ d^P_{t,t} = -(f_{1,t} - c_t) + \frac{(E^P_t p_{t+1} - f_{1,t})}{\alpha \text{Var}^P_t(p_{t+1})}. \]

Thus, production is defined solely by futures price and production costs. Number of contracts traded includes hedging part - full hedge of production, and speculation part that is inversely proportional to the risk aversion parameter. As was mentioned before, proprietary trading is not common among producers, thus we make \( \alpha \) large enough to dampen the speculative trading of producers.

Maximization of expected wealth of distributors similarly leads to

\[ I_t = \frac{E^D_t (p_{t+1} - p_t)}{\beta \text{Var}^D_t p_{t+1}}. \]

Thus, if distributors do not expect a price to change, inventories will not be filled. Distributors might have some private information that would allow them to make predictions of future spot price. Risk aversion of distributors controls how strongly they would react if next period expected spot price differs from the current spot price.

Finally, solution of financial trader maximization problem implies
\[ d_{1,t}^F = F_3^F \left( E_t^F p_{t+1} - f_{1,t} \right) - F_2^F \left( E_t^F p_{t+2} - f_{2,t} \right), \]

\[ d_{2,t}^F = F_1^F \left( E_t^F p_{t+2} - f_{2,t} \right) - F_2^F \left( E_t^F p_{t+1} - f_{1,t} \right), \]

and similarly for arbitrageur

\[ d_{1,t}^{FR} = F_3^{FR} \left( E_{t+1}^{FR} p_{t+1} - f_{1,t} \right) - F_2^{FR} \left( E_{t+1}^{FR} f_{1,t+1} - f_{2,t} \right), \]

\[ d_{2,t-1}^{FR} = F_1^{FR} \left( E_{t+1}^{FR} f_{1,t+1} - f_{2,t} \right) - F_2^{FR} \left( E_{t+1}^{FR} p_{t+1} - f_{1,t} \right). \]

where coefficients depend on expected variances and covariances and are presented in Appendix.

### 5.2 Market clearing

Now we can utilize market clearing conditions to solve for laws of motions of spot and futures prices. In appendix we derive the following expressions for futures prices

\[
\begin{pmatrix}
f_{1,t-1} \\
f_{2,t-1}
\end{pmatrix} = \Xi_1 \begin{pmatrix} f_{1,t-2} \\ f_{2,t-2}
\end{pmatrix} + \Xi_2 \begin{pmatrix} E_{t-1}^{FR} f_{1,t} \\ E_{t-1}^{FR} f_{2,t}
\end{pmatrix} + \Xi_3 \begin{pmatrix} E_{t-1}^{FR} f_{1,t-1} \\ E_{t-1}^{FR} f_{2,t-1}
\end{pmatrix} + F S_{t-1},
\]

\[ S_{t-1} = \begin{pmatrix} q_{t-1} \\ -q_{t-1} + c_{t-1}
\end{pmatrix} + \Psi_1 \begin{pmatrix} E_{t-2}^{FR} p_{t-1} \\ E_{t-2}^{FR} p_{t-1} + E_{t-1}^{FR} p_{t+1} + \Psi_2 \begin{pmatrix} E_{t-1}^{FR} p_{t} \\ E_{t-1}^{FR} p_{t+1}
\end{pmatrix},
\]

where \( \Xi_1, \Xi_2, \Xi_3, \Psi_1, \Psi_2, F \) are functions of \( F_i^{FR} \) and \( F_i^F \). And for the spot prices

\[ \theta_t - p_t = A^D E_{t-1}^D (p_t - p_{t-1}) + f_{1,t-1} - c_{t-1} - A^D E_t^D (p_{t+1} - p_t). \]

### 5.3 Solution form

Given that all of our shocks are iid across time, an given CRRA preferences we are looking for a linear equilibrium in the following form

\[ p_t = p_0 + a_0 V_t + a_1 V_{t-1} + ..., \]

and

\[ f_{1,t} = f_1 + w_0 V_t + w_1 V_{t-1} + ..., \]

\[ f_{2,t} = f_2 + g_0 V_t + g_1 V_{t-1} + .... \]
5.4 Solution procedure

to be completed

6 Results

We use a numerical example to illustrate the effect of financialization on the real economy.

6.1 Parameters

We use the following parameters, $\sigma_\theta^2 = 5$, $\sigma_c^2 = 1$, $\bar{\theta} = 5, \bar{c} = 1$, risk aversion of producers is $\alpha = 10$ to eliminate speculation motive, risk aversion of distributor, financial trader and arbitrageurs is $\beta = \gamma = \delta = 1$. Noise in distributor’s signal about future demand, $\sigma_\varepsilon^2 = 5$. Distribution of Fund’s rolling in the benchmark case: $\bar{q} = 0$ and $\sigma_\eta^2 = 1$ and precision of information about future rolling, $\sigma_\eta^2 = 1$.

6.2 Response to one-period rolling shock

We are interested in learning how the system responds to a financialization shock, and what role the learning plays in that process. Thus we consider full information case first, and then compare it with the benchmark case.

The experiment we consider is a financialization shock. The economy starts out in the steady state. Then, agents are confronted with one time 1 st.dev. rolling shock, $q$, as if the Fund suddenly has to roll a significant amount of contracts. Thus in period 2 rolling shock is realized and equals to $q_2 = \sigma_q > 0$. Given that our model assumes some noisy information about rolling size to be revealed one period in advance, in our experiment we assume that all agents get signal $m_1 = q_2$ about future shock. Of course, agents discount that signal according to its signal-to-noise ratio, however we assume realization of noise $\eta_1 = 0$.

6.2.1 Full information case

First we consider full information case. Figure 1 displays the response of spot and futures prices, and inventories to a one time financialization shock. Figure 2 shows demand of each type of agents in each period.

First of all, notice a strong reaction of futures prices in the rolling period (period 2). Second period futures prices increases by more than 10%, and first contract price decreases by about 5%. The Fund sells a substantial amount of first contracts and buys second contracts. Given zero supply of futures contracts some agents have to step in and take the opposite side. However, given uncertainty about future demand prospects, trading futures is a risky activity. Thus risk averse agents would require a premia to absorb the contracts. Therefore, future prices have to adjust - price of second futures increases and price of first futures decreases - to make trading with the Fund attractive. One can see that due to different risk aversion parameters and different trading behavior, different agents absorb different fractions of the rolling shock with arbitrageurs (front-runner).
Figure 1: Spot price, futures prices, and inventories deviations from the mean values in response to financialization shock.

Figure 2: Demand for futures contracts by agent type.
taking most of second futures. That is because they plan to offset the position next period, before
the delivery, therefore for them uncertainty is smaller. First contracts are bought by financial
traders and arbitrageurs in similar amounts, with a small fraction left for producers.

Thus we observe a reaction of futures price during the rolling period to a financialization shock.
However, futures prices respond in the period after the shock as well, and that happens because
of the way arbitrageurs trade. Arbitrageurs buy first futures contracts from the Fund and keep
them until expiration similar to financial traders. But any second period contracts sold by ar-
bitrageurs to the Fund during the rolling period would be bought back as first period contracts
in the next period. And that differs from keeping contracts until expiration by financial traders.
Roughly speaking the contracts bought by arbitrageurs have an effect on the markets twice, or
that the behavior of arbitrageurs creates a propagation mechanism and adds to the cumulative
effect of financialization shock. So heterogeneity of financial sector is important and it matters
how exactly the financialization shock is met by the market. Contrary to the result in Goldstein
and Yang (2015), larger financial sector might imply a different composition, and therefore does
not necessarily mean larger absorbing capacity.

Finally, futures prices respond one period ahead of the rolling, because information about the
rolling is revealed one period before the rolling itself. One can see that arbitrageurs sell second
period contracts in period 1. That behavior we consider as front-running, because in period 2
when that contract becomes first period contract it is sold by the Fund. Thus arbitrageurs ba-
sically sell the contract before the Fund does, or front-run. At first sight, one may be confused
that front-running happens in full information case. Indeed, in full information case every agent
observes the same information, and as in period 1 only arbitrageurs and financial traders trade
second futures, one should ask why financial traders take the opposite side of front-running deal?
But that is because trading strategies are different and financial traders will keep second contracts
until expiration, and will no longer trade on the market. Thus the futures price $f_{2,t-1}$ adjusts sub-
stantially downwards to offer arbitrageurs expected return enough to make it profitable for them
to absorb front-running shock. In other words, overlapping structure of traders and differences in
strategies imply that front-running is possible even in full info case.

Figure 1 shows that due to risk aversion nature of financial traders and arbitrageurs, and off-
setting behavior of arbitrageurs, futures prices react to a financialization shock in period preceding
the rolling, during the rolling and after it, although in a very different way. The question remains
if the effect would be bounded to financial market itself, or whether there will be further conse-
quences. And one can see that both spot price and inventories react as well. That happens because
producers change their production and distributors change their inventory policy in response to
changes in futures prices.

Risk averse producers in our model use first futures for hedging purposes. Basically producers
take futures price as given and produce having that price in mind instead of uncertain future spot
price, full hedging happens in equilibrium. Thus any changes in the futures price imply changes
in production levels, and in the amount of commodity available for production in the next period.
Smaller futures price in period 2 would imply smaller production in that period and less oil in period 3, in contrast, larger first futures price in period 3 would imply more oil in period 4. That by itself has to affect the spot price- spot price would tend to be larger in period 3 to decrease in period 4. But spot price also depends on distributors. As they expect spot price to rise by period 3, they tend to increase inventory and move oil into the future to enjoy larger price. And in period 3 they would tend to sell more oil and store less for period 4, expecting the price to fall. That is exactly what we observe: inventories build up in period 1 and 2 and dramatically decrease in period 3, and there is some rebound afterwards. The effect is not considerably strong, spot price rises by 1% at the peak and falls by 1.5% then. Inventories fluctuate in the range from -5% to 2%.

To sum up, in the full info case we observe mild real effects of financialization before, during and after the rolling period.

### 6.2.2 Benchmark case

We now proceed to the asymmetric info case. Compared to the previous case, agents now have to extract information from prices and inventories.

Figure 3 displays the dynamics of spot and futures prices. Compared to Figure 1, the effect of financialization shock is stronger in asymmetric info case. This difference is due to higher residual uncertainty as a result of imperfect learning. Changes in futures prices originate in unwillingness of financial traders and other agents to absorb the rolling shock without being compensated enough for the risk taken. In the absence of full information, agents have to extract information from endogenous prices and inventories. However, laws of motions of endogenous variables are such that perfect learning cannot be achieved, full revelation does not happen, and uncertainty remains. Thus risk averse agent facing larger uncertainty ask for larger compensation and force futures prices to move more, and in turn trigger larger real effects.
Figure 4: Information extraction
Figure 5: Demand for futures contracts by agent type.

Figure 4 displays the details of the learning process. It shows the expected value of each type of shock as a result of information extraction performed by each type of agent. First, distributors are in advantageous position as they are able to observe two shocks privately from exogenous signals - current demand and a signal about future demand. Thus observing spot price and two futures prices for them is enough to achieve perfect information extraction. Producer and arbitrageurs in contrast have one independent signal, production costs are observed by producers, and future rolling size is observed by arbitrageurs. That and observed endogenous futures prices and inventories turns out to be enough to learn the other signal - producers learn future rolling size and arbitrageurs learn production costs. Only uncertainty regarding demand shocks remains. Finally, financial traders do not possess any independent information and have to extract everything from endogenous signals. Equilibrium is such that signals are not fully revealed, in particular financial traders are not able to distinguish financialization shock from fundamental shocks. Figure 6 shows that a signal $m_t$ about future rolling gets mixed up by financial traders with fundamental shocks - demand and supply related. In particular, financial traders observing a build up in inventories and falling futures prices in period 1 tend to assign that to weak conditions in current oil market or better prospects in future oil market: they expect smaller current demand shock $\theta_t$, smaller current costs $c_t$ and better future demand $\theta_{t+1}$ that is also reflected in larger $s_t$. Importantly, observation of inventories does not prevent mixing financialization shock with fundamental shocks. That results warns from following a wide-spread practice in financial press to attribute any build up in inventories to fundamental reasons.

Compared to full information case inventories react stronger as well, both a build up is larger and a fall is twice as large. Spot price deviations are larger as well. That is a direct result of larger reaction of first futures price that forces producers to change the production, and in turn forces distributors to store more or less, depending on the period.

Finally, although in the second period agents have to absorb the same rolling shock, there
is a notable change. Arbitrageurs buy substantially smaller number of contracts, both first and second period contracts, in the rolling period (see figure 6). Instead more contracts are bought by producer, especially first period contracts, and by financial traders. Instead arbitrageurs front-runs a bit stronger (see figure 5).

Now front-running plays a somewhat different role. Financial traders are no longer aware of financialization shock to come in the next period, and might mix it with fundamental shocks. Thus, despite increased uncertainty financial traders are more willing to trade contracts in both first and second periods, because they consider it as trading based on fundamental information.

Contrary to results in Goldstein and Yang (2015) the general equilibrium effect of risk-aversion of financial traders is not clear. If financial traders are less risk averse, they are more likely to step in to the other side and thus ask for a smaller compensation and absorb better the rolling shock during the period of shock itself. On the other hand, being less risk averse in the period before the shock also means that front-runner is able to front-run more, sell more contracts and do not move market as much, as financial traders are willing to trade for smaller compensation. Thus, from a front-runner’s perspective, smaller risk aversion of financial traders in the second period is bad as it decreases the effect of the shock on the futures prices making front-running profit smaller for each contract, but smaller risk aversion in the first period allows for a larger degree of front-running, larger number of contracts sold before the rolling itself as price would not move much. That tradeoff is entirely due to richer structure of financial sector.

6.3 Heterogeneous financial sector. Term structure implications.

We have seen how agents respond to financialization shock when it comes and how spot and futures prices deviate from their mean levels as a result of agents’ adjustments. Now we would like to a step back and compare the mean levels of prices between two economies, one of which is subject to financialization shocks, and the other one that does not experience financialization shocks at
all. But in order to do that first we need to better understand the absorbing capacity of financial sector. Financial sector is populated by two types of agents - financial traders and arbitrageurs, both perform the role of absorbing shocks. Does it matter which type of agent absorbs the shock?

To answer that question we change risk aversion parameter of each type of agents, one at a time and consider pricing implications. Being less risk averse the agents would be willing to absorb more shocks, and we will study the consequences of that. So, what happens if arbitrageurs are more risk averse? What happens if financial traders are more risk averse? Is there a fundamental difference?

Figure 7 displays mean levels of spot and futures prices, and the difference $f_2 - f_1$. 'No info' case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, 'info' case allows arbitrageurs to privately observe signals about future rolling shock. Blue line - full information case with standard parameters, red line represents an economy with more risk averse agents - either financial traders are more risk averse - left 4 pictures, or arbitrageurs are more risk averse - right four pictures. Figure shows that an increase of risk aversion of either type of agents increases spot price and decreases first futures price by almost the same magnitude. That is in line with the results from Goldstein and Yang (2015). Smaller risk absorbing capacity increases the basis between first futures contract and spot price. Producers sell futures to hedge their production, and thus shift risk on financial sector. Risk averse financial traders and arbitrageurs require a compensation for risk taken. Therefore, first futures price tend to be smaller than expectation of next period spot price, to include the risk premia paid by hedgers to the financial sector. If risk becomes less attractive to financial sector due to larger risk aversion parameter, the compensation must be increased as well, thus leading to a larger difference between spot and first futures price.

However, we observe different effects on second futures prices. Second future price decreases substantially, if financial traders become more risk averse, and slightly increases, if arbitrageurs become more risk averse. Thus we observe non-trivial shift in futures curve.

Second futures is traded only by financial sector. Consider first the case of larger risk aversion of financial traders. We already have seen that spot price has to increase, whereas first futures price decreases. If second futures price were to stay fixed, arbitrageurs would be able to sell second futures at large price, wait one period and buy back cheap first futures. Therefore, in response to larger risk aversion of financial traders, the whole futures curve shifts down.

In contrast, if arbitrageurs become more risk averse, they would not be able to perform term structure arbitrage, thus in response to smaller first period price, second period price may actually go up, and move close to expected spot price.

6.4 The effect of financialization on prices, variances, and production

Now we are ready to compare mean levels of prices between two economies, one of which is subject to financialization shocks, and the other one that does not experience financialization shocks at all. Formally, we keep $\bar{q} = 0$ and change the level of $\sigma_q^2$ from zero - no financialization shocks, to
Figure 7: The effect on prices of larger risk aversion of financial traders (on the left) and arbitrageurs (on the right). Full information case. Blue line - standard parameters, red line - new parameters.

$\sigma_q^2 = 1$ as in benchmark case. As before we distinguish full information and benchmark learning cases.

Figure 8 displays mean levels of spot prices, futures prices, and futures basis, the difference between the price of more distant futures and less distant futures. Left set of pictures represents full information case, right - benchmark learning case. Red line depicts economy with no financialization shocks, blue line - economy that is subject to financialization shocks. ‘No info’ case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, ‘info’ case allows arbitrageurs to privately observe signals about future rolling shock.

Financialization decreases first futures price and increases second futures price - blue line is below red line in both pictures displaying first futures prices and is above red line for second futures prices. That is not an obvious result. Remember, that we model financialization shock as a symmetric shock, $\bar{q} = 0$, thus it is equally likely that financial market will have to absorb extra demand for first futures and extra supply of second futures, $q < 0$, or extra supply of first and extra demand for second contracts $q > 0$. Thus one might expect no changes in mean levels of futures prices due to introduction of financialization shocks, or a parallel shift in both prices.

However, financialization may be viewed as decreased capacity of financial sector to absorb the shocks. An additional source of risk is introduced, and as we have seen before it is not arbitraged away and thus gets reflected in prices and quantities. Figure 9 shows increase variances of prices and quantities. If financialization shock is unpredictable, financial sector agents start facing more risk, thus price for taking risk should be higher. But that means that to some extent financialization is equivalent to larger risk aversion of all financial sector agents. In that case price of risk also increases. But that brings us back to the results in the last subsection.
If we view financialization as decreased capacity of financial sector to absorb the shocks, a simultaneous increase of the spot price and decrease of first futures prices becomes clear, it reflects larger compensation for risk taken from producers. Notice also that effect almost disappears if financialization shock is predictable one period in advance. In that case both producers and arbitrageurs are aware of financial shock, financial traders may predict it to some extent, thus uncertainty do not increase as much due to financialization, thus virtual risk aversion do not increase so much, and thus we do not observe any substantial changes in price levels.

Now following the same logic, let's consider second futures prices. We have seen that second futures prices respond differently if risk aversion of financial traders increases versus risk aversion of arbitrageurs increases. Consider the case of no info about future rolling. Figure 8 thus displays that relative increase in virtual risk aversion of arbitrageurs is stronger than that of financial traders, and thus second futures price increases. Is that reasonable? We have seen that futures prices react substantially to financialization shock. Arbitrageurs trade along term structure curve. Thus if futures price become very volatile, then of course, arbitrageurs would cease partially trading based on other shocks, due to much larger uncertainty, which is equivalent to larger risk aversion parameter. And therefore, we assume larger second futures price, as arbitrageurs do not find an idea of selling expensive second period futures now and buying back cheap first period contract next period so attractive any longer.

Finally, as a result of smaller first futures price, production in full information case decreases by 0.76% in no front-running case and by 0.05% in front-running case with introduction of financialization shocks (see figure 10). Production in benchmark case decreases less, by 0.62% in no front-running case and by 0.44% in front-running case with introduction of financialization shocks.

6.5 Welfare

Finally, we can study the welfare effects. We consider ex ante efficiency, unconditional certainty equivalent is used to calculate welfare of each type of agents.

Consumers Consumers’ utility is given by

\[ U_C(y_t) = -\frac{1}{2}y_t^2 + (\theta_t - p_t)y_t = \frac{(\theta_t - p_t)^2}{2}, \]

where equilibrium demand \( y_t = \theta_t - p_t \) is used. Thus, expected unconditional utility of consumers equals to

\[ EU_C(y) = E \left[ \frac{(\theta_t - p_t)^2}{2} \right] = \frac{1}{2} \left( E[\theta_t - p_t] \right)^2 + \frac{1}{2} Var [\theta_t - p_t]. \]
Figure 8: Steady state mean levels - prices. Left box - full information case, right box - benchmark learning case. 'No info' case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, 'info' case allows arbitrageurs to privately observe signals about future rolling shock.

Figure 9: Variances. Left box - full information case, right box - benchmark learning case. 'No info' case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, 'info' case allows arbitrageurs to privately observe signals about future rolling shock.
Figure 10: Production. Left box - full information case, right box - benchmark learning case. ’No info’ case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, ’info’ case allows arbitrageurs to privately observe signals about future rolling shock.

Producers  Let’s first find the expected at time $t$ wealth of generation $t$ producers. The producers face realized futures price $f_{1,t}$ and costs $c_t$, and form expectations about next period $p_{t+1}$. Given equilibrium supply function and equilibrium hedging strategy, expected payoff is given by

$$E_t^P W_t^P = \frac{(f_{1,t} - c_t)^2}{2} + \frac{(E_t^P p_{t+1} - f_{1,t})^2}{\alpha Var_t^P (p_{t+1})},$$

where first term represents payoff from production that is fully hedged, and second term represents speculation. Corresponding variance

$$Var_t^P W_t^P = \frac{(E_t^P p_{t+1} - f_{1,t})^2}{\alpha^2 Var_t^P (p_{t+1})}.$$  

Indirect utility after production and trading is thus

$$CE_t^P = E_t^P W_t^P - \frac{\alpha}{2} Var_t^P W_t^P = \frac{(f_{1,t} - c_t)^2}{2} + \frac{1}{\alpha} \frac{(E_t^P p_{t+1} - f_{1,t})^2}{Var_t^P (p_{t+1})} \equiv \frac{1}{\alpha} x^T Q x,$$

where we define $x = \left( \begin{array}{c} f_{1,t} - c_t \\ E_t^P p_{t+1} - f_{1,t} \end{array} \right)$ and $Q$ is some matrix. Using unconditional moments $\mu = E x$ and $\Sigma = Var(x)$, unconditional certainty equivalent is given by
\[ CE^P = -\frac{1}{\alpha} \log \left( E e^{-\alpha C E_{after}} \right) \]
\[ = \frac{1}{\alpha} \left( \frac{1}{2} \mu^T \Sigma^{-1} \mu - \frac{1}{2} \mu^T \Sigma^{-1} (I + 2 \Sigma Q)^{-1} \mu \right) + \frac{1}{2\alpha} \log |I + 2 \Sigma Q|. \]

Welfare of financial traders and arbitrageurs may be found in a similar way. Due to complexity of expressions, they are provided in appendix only.

6.5.1 Results

Left panel in figure 11 shows welfare implications in the full information case. Two lines define the case with the Fund present (blue line) and the case without it (red line). ‘No info’ case labeled on x axis represents the case with no front-running possibilities as no information is available about future shocks, ‘info’ case allows arbitrageurs to privately observe signals about future rolling shock. Not surprisingly, in the absence of the Fund, front-running is impossible, so red lines are horizontal.

Financial traders gain from introduction of the Fund, as they can perform arbitrage activity, absorbing the Fund’s rolling demand, uncorrelated with any of the fundamental signals. Distributor gains as well - distributor to some extent performs the role of physical arbitrageur, smoothing the shocks. In contrast both producers and consumers suffer from introduction of the Fund with rolling practice. Introduction of the Fund decreases their welfare as it pushes the spot price up and decreases the production level. That logic is also applies to producers. Because given full hedge the spot price does not matter for producers, whereas both futures price and production which is a function of futures price falls. Thus producers loose from the introduction of the Fund as well if real activity is considered. However, producers may participate on the futures market not only to hedge the spot price risks. Producers in the model are free to trade any number of futures contracts, thus speculation on financial market is not restricted and introduction of the Fund would have the same effect on producers as on financial traders - producers could profit from performing arbitrage activity and absorbing the Fund’s rolling shocks. However, we do not think of that behavior as of something widely observed in reality. In general producers are restricted to hold contracts only directly related to their hedging activity, thus speculation is not allowed by most of the lenders. Therefore, to avoid the pollution of the real effects with financial gains, we make producers extremely risk averse, \( \alpha = 10 \), thus diminishing the speculation motive and respective gains. And the results shows that producers are actually loosing from the introduction of the Fund due to real losses as was discussed before.

Although we do see the negative effect of the introduction of the Fund on the real sector, the results are not particularly strong. In contrast, the welfare implications of the introduction of the Fund in the benchmark case are much stronger. The benchmark case introduces another channel, as the Fund’s rolling and front-running activity associated with that may now impede the learning process. Right panel in figure 11 displays welfare changes due to introduction of the Fund (financialization practice). Compared to the full info case, producers have larger welfare under both absence and presence of financialization shocks. However, introduction of the Fund has
Figure 11: Welfare implications of the Fund and front running. Left box - full information case, right box - benchmark learning case. X axis: with or without information about future rolling shock. Red line - without the Fund ($\bar{q} = 0, \sigma_q^2 = 0$), blue line - with the Fund ($\bar{q} = 0, \sigma_q^2 > 0$).

larger effect in benchmark case - welfare decreases by 17.5%, from 0.4 to 0.33 if no front-running is possible, and by 13.5% if front-running is present, compared to 6% in full information case.

7 Conclusion

We document a specific feature of financialization, namely investment in short-term futures contracts that require regular replacement. We build a model to show non-trivial effects of rolling on the term structure, that propagate to the real economy. The rolling shocks substantially obstruct learning and trigger large real effects. The welfare analysis shows detrimental effect of financialization on welfare of producers and consumers.

Larger financial sector does not necessarily improves the situation, as composition of financial sector matters. Statistical arbitrageurs that are not eager to take the delivery by transferring shock from one segment of the market to another, may actually add to cumulative effect of financialization shocks.

The paper raises concerns about informational role of inventories. Financial traders believe inventory levels to be key to understanding what is happening in the crude oil market. Our analysis shows that financialization shock pass through to inventories through physical arbitrage conducted by midstream companies. Thus, market participants are in danger to mix shocks originated in financial market with arrival of fundamental information, and may make wrong predictions. In reality the effect may be amplified by agents not being able to observe total inventories, but only a fraction which can be more prone to financialization shocks. In particular, in the oil market the most famous and up-to-date source of information about inventories is the Energy Information Administration (EIA) weekly report on oil stored in Cushing, Oklahoma. Cushing serves as the major trading hub and a settlement point for New York Mercantile Exchange’s oil futures contracts that have WTI as the underlying commodity. But being a settlement point Cushing is particularly
vulnerable to financial shocks and thus particularly not fit to reflect oil market conditions. Finally, the US is the only country that publishes inventory levels and WTI is the grade of crude oil used as a benchmark in oil pricing. Therefore, financialization may have even broader real effects, than we consider in the paper, and that interfere with political economy. But that lies beyond the scope of the paper and is left for future research.
8 Figures

Figure 12: Local spot oil prices, as offered by Plains All American Pipeline. Each line represents one particular location in the United States and shows the prices offered in that location in March, 2014. The picture shows a strong comovement of spot prices, all following the changes in the WTI traded on futures exchange.
Figure 13: Local spot oil prices, as offered by Plains All American Pipeline. X axis shows different locations in the United States. Each line shows daily prices offered in each location. The picture shows a strong comovement of spot prices, all following the changes in the WTI traded on futures exchange.
Figure 14: Open interest in crude oil futures contracts traded at the NYMEX (code CL) by maturity as of November 16, 2015. On the x-axis is the number of years before the settlement date. Source: the CME Group website. Open interest quickly decreases with maturity. The nearby contract expires on November 20, 2015, thus we observe a drop in open interest at the beginning of the curve.
Figure 15: Oil inventories: total inventory and oil stored at storage facility in Cushing, Oklahoma - major trading hub and a settlement point for WTI on the NYMEX. Information about inventories in Cushing is published each week, and represents the most up-to-date signal about oil inventories. However, being a settlement point Cushing is prone to financial shocks, as physical arbitrage triggered by the effect of rolling shock on the futures curve, is likely to involve storage of oil in Cushing, and thus financialization shock will be reflected immediately in Cushing storage volumes.
9 Appendix

9.1 Oil inventories in media

EIA: On April 8, 2015, the EIA (U.S. Energy Information Administration) reported that weekly crude oil stockpiles increased by 10.95 MMbbls (million barrels) for the week ending April 3. Last week also saw inventories increase by 4.8 MMbbls. This massive inventory buildup signals weak demand in the oversupplied crude oil market.

WSJ: Oil prices slid Wednesday after weekly storage data showed that U.S. stockpiles grew more than expected last week, as imports rose and refineries processed less crude. “The oil inventory raised concerns about weak demand,” said Phil Flynn, analyst at the Price Futures Group in Chicago.

FT.com: Concerns about weak demand amid lower economic growth weighed on oil prices with a rise in US inventories adding to the bearish sentiment.

Seeking alpha: EIA Report Sends A Bearish Signal. This week’s U.S. petroleum inventory release was bearish from the supply/demand fundamentals perspective.

Federal Reserve Bank of Dallas: Declining inventories signal increased demand

Energy outlook: An inventory buildup can be interpreted either as a signal of weaker than anticipated demand or that demand is expected to grow in the future. Lean inventories can suggest that demand is stronger than forecast or that demand is expected to slack in the future. A balanced market is typically considered about 4.2 months of supply.

9.2 Solution

to be completed

9.3 Welfare

The formula that we use

\[ Ee^{-x^TQx} = E\exp(-x^TQx) \]

\[ = \frac{1}{\sqrt{(2\pi)^2|\Sigma|}} \int \exp(-x^TQx) \exp\left(-\frac{1}{2}(x-\mu)^T \Sigma^{-1} (x-\mu)\right) \, dx \]

\[ = \frac{1}{\sqrt{(2\pi)^2|\Sigma|}} \int \exp\left(-\frac{1}{2}\left(x^T (I+2Q\Sigma) \Sigma^{-1} x - 2\mu^T \Sigma^{-1} x - \frac{1}{2} \mu^T \Sigma^{-1} \mu\right)\right) \, dx \]

\[ = \frac{1}{\sqrt{(2\pi)^2|\Sigma|}} \exp\left(-\frac{1}{2} \left( \mu^T \Sigma^{-1} \mu - \mu^T \Sigma^{-1} (I+2Q\Sigma)^{-1} \mu \right) \right) \int \exp\left(-\frac{1}{2} \left( (x - \tilde{\mu}) (\tilde{\Sigma})^{-1} (x - \tilde{\mu}) \right) \right) \]

\[ = \frac{1}{\sqrt{|I+2Q\Sigma|}} \exp\left(-\frac{1}{2} \left( \mu^T \Sigma^{-1} \mu - \mu^T \Sigma^{-1} (I+2Q\Sigma)^{-1} \mu \right) \right) \]

where
\[ \tilde{\mu} = (I + 2Q\Sigma)^{-1}\mu, \]
\[ \tilde{\Sigma} = \Sigma (I + 2Q\Sigma)^{-1}. \]

Therefore,
\[
CE = \frac{1}{\alpha} \log \left( E e^{-x^T Q x} \right),
\]
\[
= \frac{1}{\alpha} \left( \frac{1}{2} \mu^T \Sigma^{-1} \mu - \frac{1}{2} \mu^T (I + 2\Sigma Q)^{-1} \mu \right) + \frac{1}{2\alpha} \log |I + 2Q_2\Sigma|.
\]

where
\[
\mu = E(x),
\]
\[
\Sigma = Var(x).
\]

Thus, knowing \( Q \) and moments of \( x \), we can found the welfare of each type of agents.

**Distributors**
\[
Q^D = \frac{1}{2Var_{t-1}^D p_t}
\]
\[
x^D = E_{t-1}^D p_t - p_{t-1}
\]

**Producers** Generation \( t - 1 \) producers
\[
Q^P = \begin{pmatrix}
\alpha \\
2 \\
0 \\
0
\end{pmatrix}
\]
\[
x^P = \begin{pmatrix}
\tilde{f}_{1,t-1} - c_{t-1} \\
E_{t-1}^P p_t - \tilde{f}_{1,t-1}
\end{pmatrix}
\]

**Financial traders** Generation \( t - 1 \) traders
\[
Q^F = \frac{1}{(Var_{t-1}^F (p_{t+1}) Var_{t-1}^F (p_t) - cov_{t-1}^2 (p_t, p_{t+1}))} \begin{pmatrix}
Var_{t-1}^F (p_{t+1}) & -cov_{t-1}^F (p_t, p_{t+1}) \\
-cov_{t-1}^F (p_t, p_{t+1}) & Var_{t-1}^F (p_t)
\end{pmatrix}
\]
\[
x^F = \begin{pmatrix}
E_{t-1}^F p_t - \tilde{f}_{1,t-1} \\
E_{t-1}^F p_{t+1} - \tilde{f}_{2,t-1}
\end{pmatrix}
\]
9.4 Solution procedure

to be completed